A STATISTICAL EVALUATION OF JOINT RANGE DATA

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AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This report was prepared by the Anthropology Section, Biophysics
Branch, Aero Medical Laboratory, Wright Air Development Center,
under Project 7214, Task 71727, entitled, "Biokinematics and Work-
space". The analysis of the data was carried out by Antioch College
under Contract No. AF 18(600)-30. Mr. Emanuel initiated the study
and Mr. Truett carried out the statistical phases of the work.

Many people aided materially in the execution of the study and the
production of the report. Dr. Wilfrid T. Dempster, on whose work
this study is based, provided valuable advice. Mr. H. T. E. Hertzberg,
Chief of the Anthropology Section, critically reviewed the manuscript
and contributed many constructive suggestions. The illustrations were
done by Mrs. Cleona Allen and Miss Dorothy B power, and Lt. Glenn
Aller. served as the model. Mr. Edmund Church of Antioch College
provided advice on statistical matters. The physical preparation of
the report was done by Mr. Horace B. Clark of the Anthropology Sec-
tion.

This Report is UNCLASSIFIED.

ABSTRACT

This study reanalyzes the data concerning the range of motion of human body joints published in WADC TR 55-159, Space Requirements of The Seated Operator, by W. T. Dempster. The reanalysis is intended to present the information in a form more applicable to Air Force design problems. An analysis of variance of 43 joint movements for four subgroups originally selected on the basis of physique revealed that 12 body movements (28%) were related to physique. The subgroup statistics were combined to yield summary statistics for the total sample of 39 young men. Design ranges were derived from these total group values. Descriptions and illustrations of joint movements are included.

PUBLICATION REVIEW

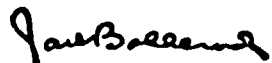This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

INTRODUCTION

Investigations into the range of motion of body joints have been relatively numerous, resulting in a large number of reports which present information on this subject (see bibliography, page 20). The majority of these reports are concerned with questions of definition and methodology and are generally weak on statistical information. Some reports which include results often do not include accurate descriptions of the motions studied (Glanville and Kreezer, 1937; Batch, 1955), and at least two do not give an indication of the number of subjects studied or source of the results (Batch, 1955; TM No. 8-640, 1956).

Data on joint ranges have been gathered, for the most part, through the use of goniometers of some form or other. One of the common types of goniometers resembles a protractor with a movable arm. The center of zero point of the protractor is set at the approximate joint center and the movable arm is affixed to the active member. The practical difficulty of such devices is that differing types of instruments may give slightly different results. In addition, variant positioning techniques produce noncomparable data.

A recent study by Dempster (1955) corrected many of these shortcomings of previous studies. Dempster used a photographic method for measuring the range of movement of body joints (Dempster, 1955, pp 31-36). There are several obvious advantages to photographic recording of body positions. The standardization of positions is easier, because the subject is not required to hold an uncomfortable posture for a length of time. The gathering of data is relatively rapid, and permanent records are obtained which can be reanalyzed if necessary. Furthermore, the number of motions recorded by Dempster exceeds that of any other statistically valid sample. Dempster's statistics are reported, however, for four subgroups selected on the basis of physique and not for the entire sample of 39.

This study reanalyzes Dempster's results so as to combine the subgroup data into more convenient tabulations for the designer.

SECTION II

MATERIALS AND METHODS

The joint range data published by Dempster are based on a sample of 39 young men. Measurements were taken on the right side of the body for right-handed subjects and on the left side of the body for left-handed individuals. The data as published summarize motions for four subsamples of the total series of 39 college students. The subsamples are based on physique as estimated by somatotype ratings. Eleven were of median body build, seven were extremely rotund (endomorphs), eleven were extremely muscular (mesomorphs) and ten were extremely thin (ectomorphs). (Dempster, 1955, pp. 22-25). The series, then, was not random with respect to somatotype (Sheldon, Stevens and Tucker, 1940). This may affect the results if the data for the four physique groups are combined, since slight differences in joint mobility among the various body types have been reported (Sinelnikoff and Grigorowitsch, 1931; Dempster, 1955, pp. 106-109).

TABLE I

Comparison of Joint Motion Sample With Air Force Sample

	Present Sample N = 39		USAF Sample N = 4000+	
	M	**S.D.**	**M**	**S.D.**
Age	21.1 yrs.	3.3	27.9 yrs.	4.2
Weight	169.7 lbs.	36.3	163.7 lbs.	20.9
Stature	70.5 inches	2.8	69.1 inches	2.4
Acromion Height	57.7	2.5	56.5	2.3
Suprasternale Height	57.2	2.4	56.3	2.2
Crotch Height	33.2	2.1	32.8	1.7
Waist Circumference	32.0	4.8	32.0	3.0
Thigh Circumference	22.6	2.8	22.4	1.7
Sitting Height	36.2	1.5	35.9	1.3
Shoulder-Elbow Length	14.3	.8	14.3	.7
Knee Height, Sitting	21.7	1.0	21.7	1.0

Table I compares Dempster's sample with the 1950 Air Force sample (Hertzberg, Daniels and Churchill, 1954). No statistical tests of significance were performed. However, certain general observations may be made concerning these two samples. Dempster's sample is 6.8 years younger, 6.0 pounds heavier and 1.4 inches taller than the Air Force series. In general those anthropometric measures which are closely related to weight are one and one half to two times more variable in the joint motion study sample.

The mobility of joints is reported to be directly affected by the sex, age and physical constitution of the individual. Sinelnikoff and Grigorowitsch (1931) investigated the magnitude of the differences in joint mobility due to each of these factors. They tend to generalize and state that constitution affects joint motion without stating which particular joints are affected. In general, however, not only Sinelnikoff and Grigorowitsch, but also Dempster (pp. 106-8) conclude that thin men have greater joint mobility than muscular men, who in turn have more mobility than rotund men.

Since body type was the single criterion according to which Dempster's sample was subdivided, it seemed worthwhile to test statistically whether physique was related to joint mobility. The results of such a test should not only serve to compare Dempster's findings with those of Sinelnikoff and Grigorowitsch, but will also help indicate whether or not the differences associated with physique are too pronounced to warrant combining the data of the various subgroups. The analysis of variance is a convenient tool to use in this instance. For in addition to being able to determine the significance of the differences between the subgroup means, it is also possible to derive the total group variance and thus a total standard deviation for the combined group.

An analysis of variance in this study will indicate whether the difference between subgroups for the movements are greater than is to be expected on the basis of chance alone. Since the groups are segregated on the basis of physique, if statistical significance occurs, joint mobility would seem to be related to physique. Not all joint movements would be related to the same degree with physique, and some may appear to be not related at all.

Starting with the data from Table 5, pp 107-108 and Table 6, pp 110-112 in Dempster's report, the following computational steps were taken for each of the 43 joint movements. The "within sum of squares" (SS_w) were computed by adding the products obtained by multiplying each subgroup variance by the number of subjects in that subgroup. The total number of subjects in the subgroup was used, since this number was the divisor used in computing the subgroup standard deviation. The "between sum of squares" (SS_b) were computed in the following fashion. The means for each subgroup were multiplied by the number of subjects in that subgroup. The sum of these products was divided by the total number of subjects to give the total group mean for that joint motion. The difference between the total and each subgroup mean was squared and multiplied by the number of individuals in each category. These products were then added, the sum being the between sum of squares. The total group sum of squares was obtained by adding the within sum of squares and the between sum of squares.

Each of the sums of squares was divided by the corresponding degrees of freedom (35 for "within", 5 for "between" and 38 for the total) to obtain the mean squares or variance estimates. The square root of the total variance estimate is the standard deviation for the total group. The variance or "F" ratio was then computed by dividing the between mean square by the within mean square for each joint motion.

$$F = \frac{\text{Between Mean Square}}{\text{Within Mean Square}}$$

3

SECTION III

RESULTS

A. Analysis of Variance

Reference to a table of F ratios indicated that, with 3 degrees of freedom for the between mean square and 35 degrees of freedom for the within mean square, a ratio of 2.37 was significant at the 5% level and a ratio of 4.40 was significant at the 1% level. This means that for those motions where the F ratio is equal to or greater than the 5% level value, the difference among the subgroups are greater than would be expected by chance alone 95% of the time. Out of a total of forty-three movements studied, twelve or 28% had F ratios which were significant at either the 5% or 1% level (Table II).

TABLE II

F Ratios Significant at the 5% Level

		F
1.	Wrist, Flexion	4.04
2.	Shoulder, Adduction	4.06
3.	Hip, Lateral Rotation, Sitting	3.05
4.	Knee, Voluntary Flexion, Standing	3.35
5.	Ankle, Extension	4.14

F Ratios Significant at the 1% Level

		F
6.	Wrist, Total Flexion-Extension Angle	4.92
7.	Hip, Flexion	4.53
8.	Knee, Voluntary Flexion, Prone	8.19
9.	Knee, Forced Flexion, Prone	8.34
10.	Knee, Forced Flexion, Kneeling	14.38
11.	Ankle, Flexion	5.49
12.	Ankle, Total Flexion-Extension Angle	7.00

Thus there appears to be a significant relationship between range of joint motion and physique for about one-quarter of the cases. Some of these motions are probably correlated with each other, such as the four knee movements, the two wrist movements, and the three ankle movements. The F tests corresponding to these motions therefore cannot be considered independent tests; separate tests on motions which are correlated are to some extent spurious. This condition of possible nonindependence should be considered in the interpretation of these results. Table III ranks the mean mobility values of the four subgroups for the twelve motions statistically related to physique. The rotund group in every case has the lowest mobility, and the thin group has the highest mobility in seven out of the twelve cases. A general ranking from low to high is rotund, muscular, median, and thin.

TABLE III

Rank of Mean Mobilities of Physique Groups

	LOW			HIGH
Motion	**1**	**2**	**3**	**4**
1. Wrist, Flexion	Rotund	Muscular	Median	Th..
2. Shoulder, Adduction	Rotund	Muscular	Median	Thin
3. Hip, Lateral Rotation, Sitting	Rotund	Muscular	Median	Thin
4. Knee, Voluntary Flexion, Standing	Rotund	Median	Thin	Muscular
5. Ankle, Extension	Rotund	Thin	Median	Muscular
6. Wrist, Total Flexion-Extension Angle	Rotund	Muscular	Thin	Median
7. Hip, Flexion	Rotund	Thin	Median	Muscular
8. Knee, Voluntary Flexion, Prone	Rotund	Median	Muscular	Thin
9. Knee, Forced Flexion, Prone	Rotund	Median	Muscular	Thin
10. Knee, Forced Flexion, Standing	Rotund	Muscular	Median	Thin
11. Ankle, Flexion	Rotund	Muscular	Median	Thin
12. Ankle, Total Flexion-Extension Angle	Rotund	Thin	Muscular	Median

In spite of th. ract that Dempster's series was highly selected, the subgroup data
are pooled and presented below. This was deemed a reasonably valid procedure for
various reasons.

1. Only about one-quarter of the movements are significantly related to physique.

2. Some of the differences in mobility among the various physique groups will
   undoubtedly be cancelled out if the group statistics are pooled.

3. The differences among subgroup mobility statistics are generally small from
   a practical standpoint.

4. Dempster's study is more complete from all standpoints than any other study.
   Thus, in spite of the selectedness of the sample, the advantages resulting
   from the completeness of the study and the accurate descriptions of procedures
   probably outweigh any other inadequacies.

B. Joint Movements

In this subsection each joint movement is described and illustrated. The mean
values were taken from Dempster's report and the standard deviations have been
derived from the analysis of the subgroup data. Design ranges of the mean plus and
minus two standard deviations (S. D.) are presented for each motion for the entire
series of thirty-nine young men. These design ranges include about 95% of the sam-
ple. All values are expressed in degrees.

A summary table of the statistical analysis appears in the Appendix.

Many of the movement descriptions involved the body segment link line, which Dempster defines as "The straight line which interconnects two adjacent joint centers..." (p. xix). These were estimated on the photographs in order to obtain measurements. For the practical purposes to which the data of this report may be applied, the link line can be approximated by the long axis of the body segment in question.

No. 1 - Wrist, Flexion

Mean	90
S. D	12
Mean + 2 S. D.	114
Mean - 2 S. D.	66

The subject stands with the dorsal sur-
face of the hand on a table, the reference
plate pressed against the palm. The fore-
arm is supinated and maximally flexed.
The angle is measured between the forearm
link line and the reference plate.
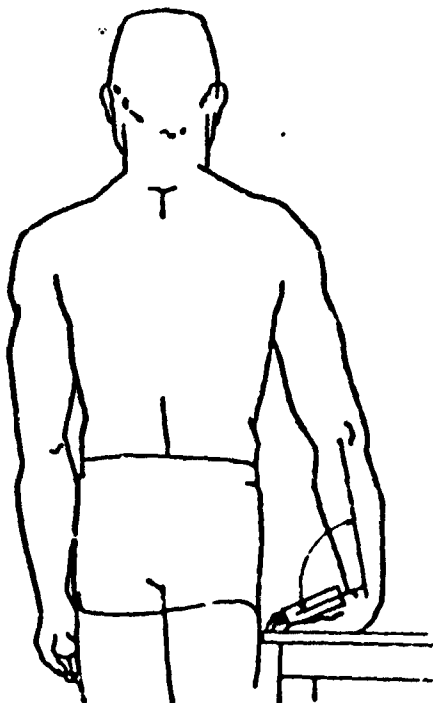
... - Wrist Extension		Total Flexion-Extension Angle
Mean	99	189
S. D.	13	21
Mean + 2 S. D.	125	231
Mean - 2 S. D.	73	147

The subject stands with his fingers
... away from his body, his palm
... table. The forearm is vertical
... pinated. The wrist is bent to max-
... extension. The angle is measured
... en the forearm link line and the
... zontal plane represented by the top
... the table. The total angle is measured
... en the maximum flexion and max-
... extension positions.
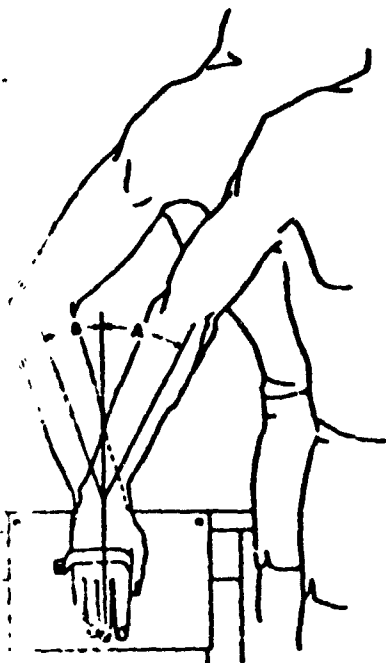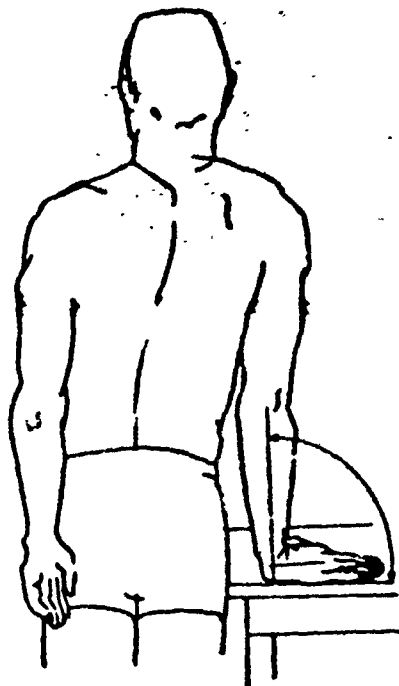
No. 3 - Wrist, Adduction and Abduction

	A-Adduction	B-Abduction	Total
Mean	47	27	74
S. D.	7	9	13
Mean + 2 S. D.	61	45	100
Mean - 2 S. D.	33	9	48

The subject stands with the palm of the
hand held flat against the vertical back of
the work table by the restraining gear. The
forearm is bent at the wrist to extreme
adduction (towards the body) and then to
maximum abduction (away from the body).
The angles are measured between the line of
the forearm link and a line passing through
the center of the third digit. The total angle
is measured between the maximum adduct-
ion position and the maximum abduction
position.

No. 4 - Forearm, Supination

Mean	113
S.D.	22
Mean + 2 S.D.	157
Mean - 2 S.D.	69

The subject sits at a table with his upper arm vertical and the forearm horizontal on the table. A rod is grasped in the closed hand. The forearm is supinated (rotated palm upward) to the maximal position. The angle is measured between the vertical and a line passing through the long axis of the grip rod at the thumb end.
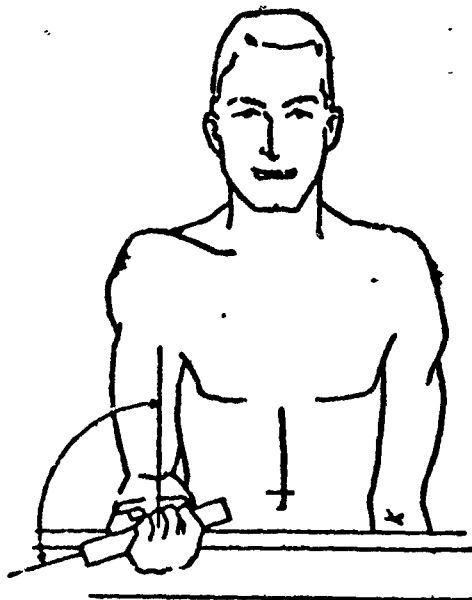
|		Total Pronation-
No. 5 - Forearm,Pronation		**Supination Angle**
Mean	77	190
S.D.	24	30
Mean + 2 S.D.	125	250
Mean - 2 S.D.	29	130

The subject sits at a table with the upper arm vertical and the forearm horizontal on the table. A rod is grasped in the closed hand. The forearm is pronated (rotated palm downwards) to the maximum position. The angle is measured between the vertical and a line passing through the long axis of the grip rod at the thumb end. The total angle is measured between the maximum supiration and maximum pronation positions.
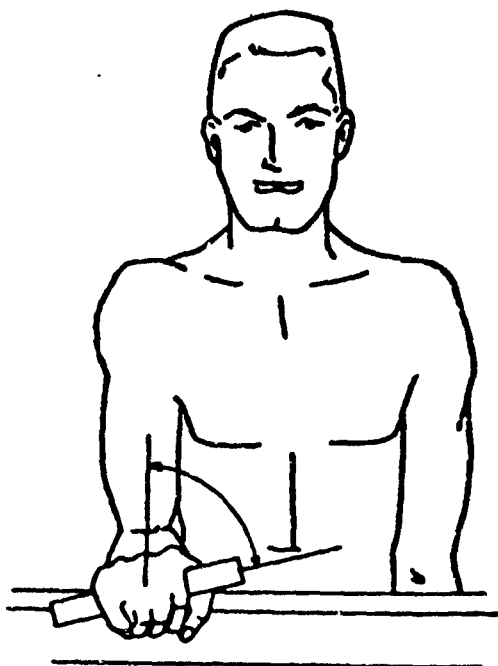
No. 6 - Elbow Flexion

|	
Mean	142
S. D.	10
Mean + 2 S. D.	162
Mean - 2 S. D.	122

The subject sits with his side towards the table, with the back of the hand facing laterally. The arm is supported horizontally on a block, the forearm bent to extreme flexion with hand over the shoulder. The angle is measured between the projection of the arm link line and the forearm link line.
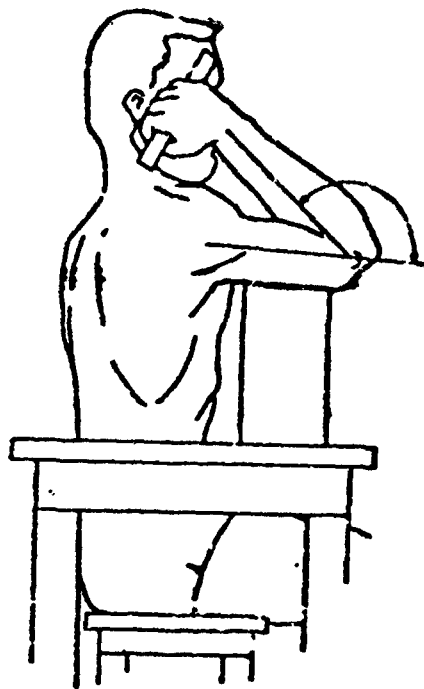
No. 7 - Shoulder, Flexion and Extension

	A-Flexion	B-Extension	Total
Mean	158	61	249
S. D.	12	14	19
Mean + 2 S. D.	212	89	287
Mean - 2 S. D.	164	33	211
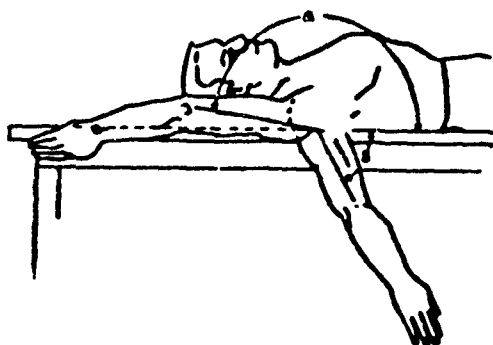
The subject lies supine upon the table, the straightened limb free to rotate past the edge of the table. In flexion, the arm is swung in the sagittal plane to the maximum overhead position, and the angle is measured between the arm link line and the table horizontal. In extension, the arm hangs to the maximum limit of movement in the sagittal plane over the edge of the table. The angles are measured between the arm link line and the table horizontal. The total angle is measured between the arm link line in the flexion position and the arm link line in the extension position.

No. 8 - Shoulder, Adduction and Abduction

	A-Adduction	B-Abduction	Total
Mean	48	134	182
S. D.	9	17	20
Mean + 2 S.D.	66	168	222
Mean - 2 S.D.	30	100	142

The subject lies supine upon the table with a horizontal reference rod resting across the chest. In adduction, the straightened arm is swung maximally across the chest to the opposite side of the body. In abduction the straightened arm is hanging laterally over the edge of the table, to the limit of abduction perpendicular to the long axis of the body. The two angles are measured between the arm link line and a line perpendicular to the reference rod. The total included angle is measured between the two extreme positions of the arm link lines.
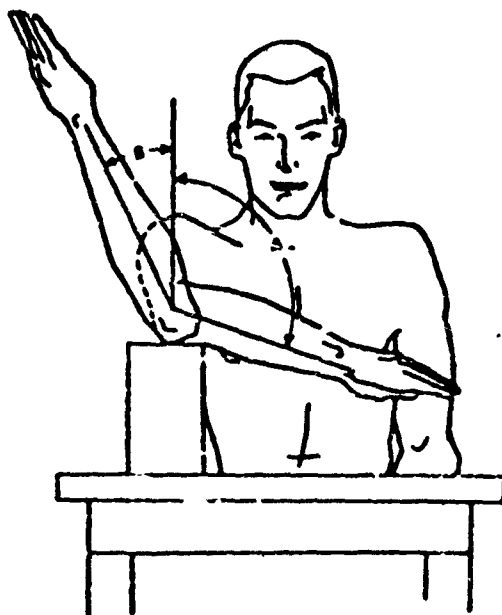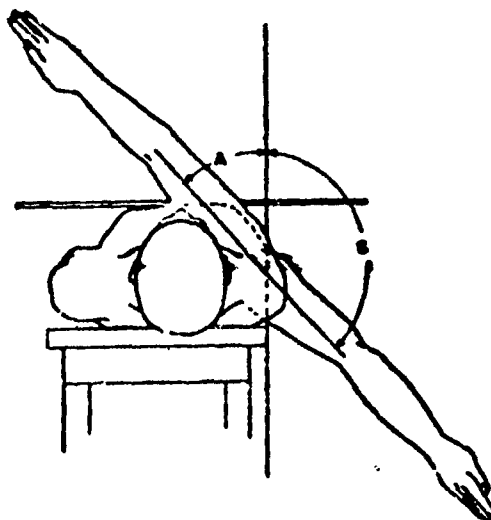
No. 9 - Shoulder, Medial and Lateral Rotation

	A-Medial Rotation	B-Lateral Rotation	Total
Mean	97	34	131
S. D.	22	13	24
Mean + 2 S. D.	141	60	179
Mean - 2 S. D.	53	8	83

The subject sits with the arm supported in a horizontal position by a block resting on the table, the forearm flexed to a vertical position. In medial rotation, the forearm is swung toward the midline to the maximum position In lateral rotation, the forearm is swung outward to the limit of movement. The two angles are measured between the forearm link line and the vertical. The total angle is measured between the link lines of the maximum lateral and medial positions.

No. 10 - Hip, Flexion

Mean	113
S.D.	13
Mean + 2 S. D.	139
Mean - 2 S. D.	87

The subject lies supine upon the table with a block under the buttock. A special pelvic guide is adjusted so that it lies over the right and left anterior-superior spines of the ilium and the pubic symphysis. A reference rod attached to the pelvic guide is adjusted to a horizontal position. The knee is bent and the hip is maximally flexed in the sagittal plane until the reference rod begins to tilt away from the horizontal. The angle is measured between thigh link line and the reference rod.
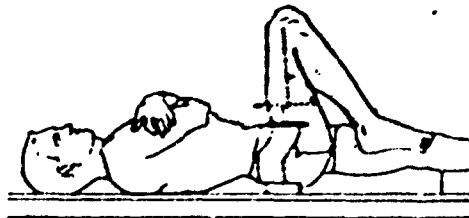
No. 11 - Hip, Adduction and Abduction

	A -Adduction	B -Abduction	Total
Mean	31	53	84
S.D.	12	12	14
Mean + 2 S. D.	55	77	112
Mean - 2 S. D.	7	29	56
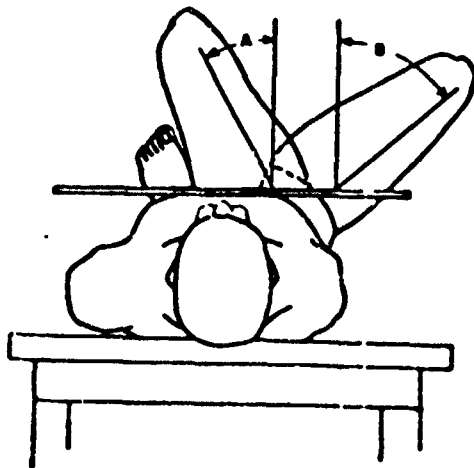
The subject lies supine upon the table. A horizontal reference rod is placed across the anterior-superior spines of the pelvis. The knee is bent to 90°, keeping the heel in contact with the table top. In adduction the knee and thigh are turned in toward the midline of the body. In abduction, the knee and thigh are turned outward. The two angles are measured between the thigh link line and a line perpendicular to the pelvic reference rod. The total angle is measured between the thigh link lines in the extreme abduction and adduction positions.

No. 12 - Hip Medial and Lateral Rotation, Prone

	A -Medial	B -Lateral	Total
Mean	39	34	73
S. D.	10	10	16
Mean + 2 S. D.	59	54	105
Mean - 2 S. D.	19	14	41

The subject lies prone upon the table with the knee bent to 90° and the leg in a vertical position. A horizontal reference rod is placed transversely across the back of the pelvis. In medial rotation, the leg is swung inward. In lateral rotation, the leg is swung outward. The two angles are measured between the leg link line and a perpendicular to the horizontal reference rod. The total angle is measured between the leg link lines in the maximum medial and lateral positions.
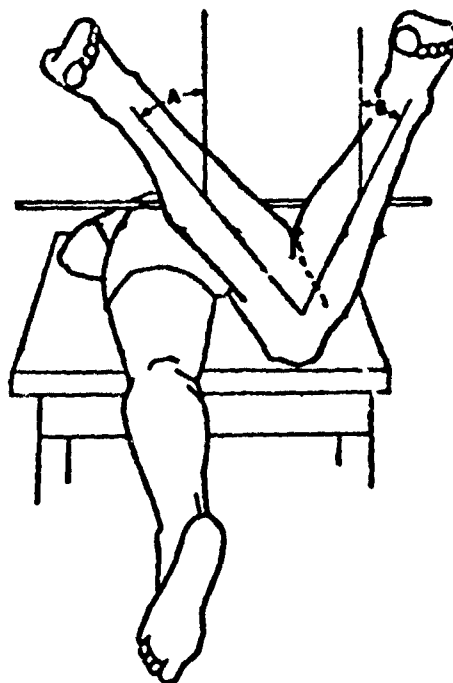
No. 13 - Hip, Medial and Lateral Rotation, Sitting

	A -Medial	B -Lateral	Total
Mean	31	30	61
S. D.	9	9	14
Mean + 2 S. D.	49	48	89
Mean - 2 S. D.	13	12	33

The subject sits on the table with the thigh horizontal and the leg hanging over the edge. In medial rotation, the lower leg and foot are swung medially to the limit of rotation. In lateral rotation, the lower leg and foot are swung laterally to the limit. Both angles are measured between the leg link line and the vertical. The total angle is measured between the leg link lines for the extreme lateral and medial positions.
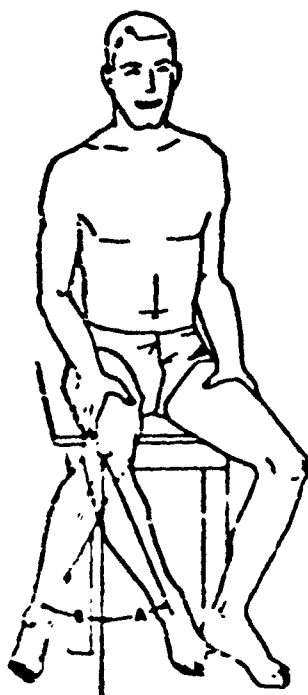
No. 14 - Knee, Voluntary and Forced
Flexion, Prone

	A -Voluntary Flexion	B -Forced Flexion
Mean	125	144
S. D.	10	9
Mean + 2 S. D.	145	162
Mean - 2 S. D.	105	126
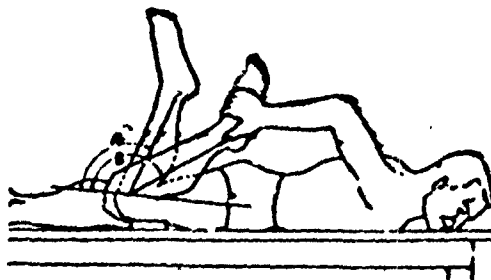
The subject lies prone on the table top, the region above the kneecap supported by a small block. The knee is flexed to the maximum position possible without assistance. In forced flexion, the subject grasps the foot, forcing the calf tightly against the thigh. The angles are measured between the leg link line and the projection of the thigh link line.
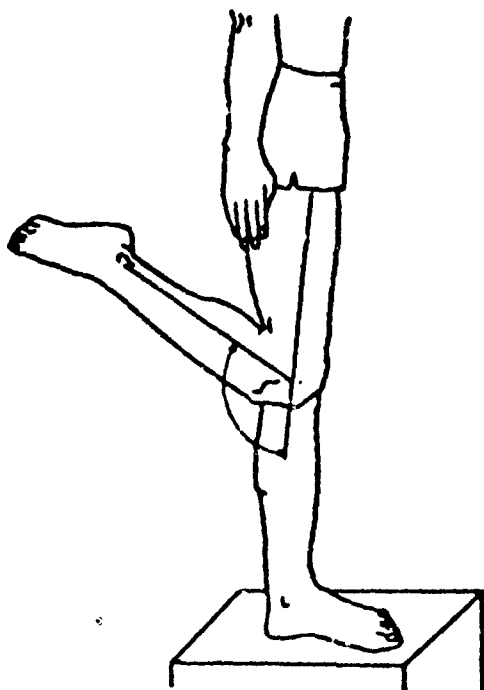
No. 15 - Knee, Voluntary Flexion, Standing

Mean	113
S. D.	13
Mean + 2 S. D.	139
Mean - 2 S. D.	87

The subject stands with his weight on one foot. On the test limb the thigh is held straight and the leg is slowly flexed at the knee to the maximum. The angle is measured between the projection of the thigh link line and leg link line.

16 - Knee, Forced Flexion, Kneeling

Mean	159
S. D.	9
Mean + 2 S. D.	177
Mean - 2 S. D.	141

The subject assumes a kneeling position, with the trunk vertical and the weight of the body forcing maximum knee flexion. The angle between the thigh link line and projection of the leg link line is measured.
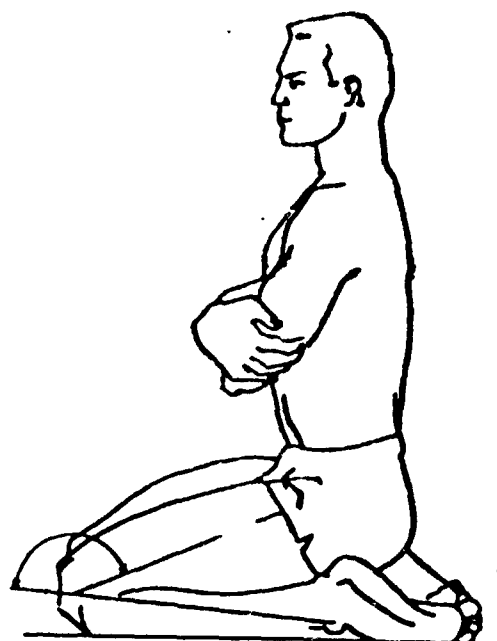
No. 17 - Knee, Medial and Lateral Rotation
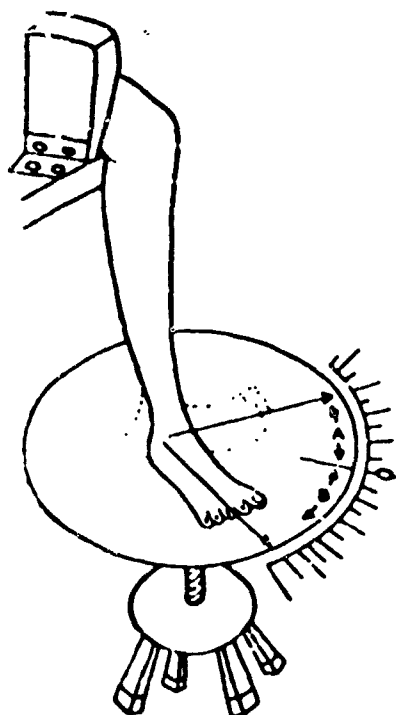
	A - Medial Rotation	B - Lateral Rotation	Total
Mean	35	43	78
S. D.	12	12	',
Mean + 2 S. D.	59	67	110
Mean - 2 S. D.	11	19	46

The subject stands beside the table, with his upper leg about 45° to the vertical. The test foot is resting on a turntable with the lower leg vertical and the ankle above the center of the turntable. The knee is held against a block on the table. The experimenter rotates the turntable medially or laterally to the limit of motion. The angle between the toe-forward position and the extreme medial and lateral positions are recorded. The total angle between the medial and lateral rotation positions is measured.

18 - Ankle, Flexion and Extension

	A-Flexion	B-Extension	Total
Mean	35	38	73
S. D.	7	12	14
Mean + 2 S. D.	49	62	101
Mean - 2 S. D	21	14	45

The subject stands sideways on a box with
the thigh horizontal and the foot on a table top.
In flexion the body and leg are bent forward to
the maximum flexed position of the ankle. In
extension the ankle on the side being measured
straightened maximally, which is done by
arching the trunk and the other leg backward.
The angles are measured between the vertical
and the leg link line in the flexion and extension
positions. The total angle is measured between
the leg link lines in the maximum flexion and
extension positions.
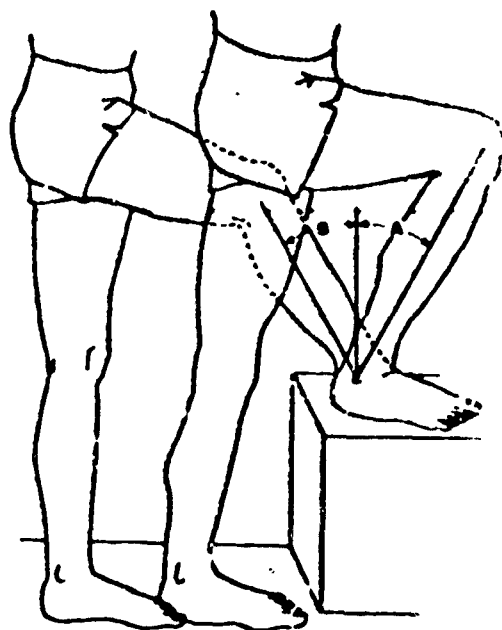
No. 19 - Foot, Inversion and Eversion

	A Inversion	B-Eversion	Total
Mean	24	23	47
S. D.	9	7	11
Mean + 2 S. D.	42	37	73
Mean - 2 S. D.	6	9	21
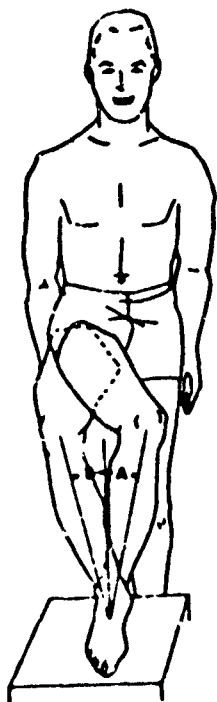
The subject stands with his foot on a box,
toes pointing directly forward. In inversion,
the knee and leg are swung inward with the
foot sole kept horizontally on the box surface.
In eversion, the knee and leg are swung out-
ward. The angles are measured between the
leg link line and the vertical. The total angle
is measured between the leg link lines in the
maximum inverted and everted positions.

No. 20 - Grip Angle

Mean	192
S. D.	7
Mean + 2 S. D.	116
Mean - 2 S. D.	88

The subject stands erect, the arm,
forearm and hand hanging vertically. A
1 1/8-inch wooden grip rod is held loosely
in the hand. The angle is measured be-
tween the forearm link line and a line run-
ning through the long axis of the reference
rod at the thumb end.

SECTION IV

SUMMARY AND CONCLUSIONS

Joint mobility data published by Dempster (1955) have been reanalyzed and
presented in a form intended to be more applicable to A r Force design problems.

The sample consisted of 39 young men on whom 43 body joint movements were
studied. Summary statistics, descriptions, and illustrations of the movements are
presented.

Data in this report can be used to provide estimates of the normal range of joint
mobility. The mean plus and minus two standard deviations, which include about
95% of the sample, can be used to serve as reference standards for testing equipment.
For instance, in a piece of equipment such as a pressure suit an effort should be made
to provide mobility as near as possible to the value of the mean + 2 S. D. Thus the
mobility of few individuals will be restricted, and in this case only at the limit of
motion. It is, however, not to be expected that any type of pressure suit will achieve
complete mobility for the wea. , although it is nevertheless desirable to strive to-
ward this end, and any restriction allowed should be minimal. Acceptable restrictions
will necessarily have to be arbitrary, determined in every case by a consideration of
the problem at hand. Joint range data can also serve as a guide to movement capabili-
ties in crewstation design, particularly in the location of controls. Controls should
be placed so that the operator does not have to attain difficult or maximum joint po-
sitions.

APPENDIX

SUMMARY TABLE OF JOINT MOVEMENT RANGES[1]

Values Are In Degrees
N = 39

Joint and Type of Movement	Mean	S.D.	M + 2 S.D.	M − 2 S.D.	SS_x	SS_b	F - ratio
WRIST:							
Flexion	80	12	114	66	3612.68	1250.02	4.04*
Extension	82	13	125	73	4669.09	1088.63	2.72
Total	189	21	231	147	10928.37	4612.78	4.92**
Adduction	27	9	45	9	2851.90	73.97	.30
Adduction	47	7	61	33	1472.29	11.04	.09
Total	74	13	100	48	5851.19	113.13	.22
FOREARM:							
Supination	113	22	157	69	14699.03	2877.44	2.28
Pronation	77	24	125	29	18883.31	1753.43	1.08
Total	196	30	250	130	29010.69	5231.72	2.10
ELBOW:							
Flexion	142	10	162	122	3249.92	119.92	.43
SHOULDER:							
Flexion	188	12	212	164	4502.65	474.15	1.23
Extension	61	14	89	33	5925.68	791.73	1.56
Total	249	19	287	211	11604.55	1470.38	1.48

[1]Computed from Dempster, 1955, pp. 107-108, 110-112.
*Significant at 5% level of confidence
**Significant at 1% level of confidence

SUMMARY TABLE OF JOINT MOVEMENT RANGES (Cont'd)

Joint and Type of Movement	Mean	S.D.	M+2S.D.	M-2S.D.	SS_w	SS_b	F-ratio
SHOULDER: (Cont'd)							
Adduction	134	17	168	100	8853.54	1046.56	1.38
Abduction	48	9	66	30	1925.73	669.65	4.06**
Total	182	20	222	142	12224.73	2831.38	2.69
Medial Rotation	97	22	141	53	18042.19	117.57	.08
Lateral Rotation	34	13	60	8	5478.65	448.87	.96
Total	131	24	179	83	19976.13	633.50	.37
HIP:							
Flexion	113	13	179	37	4515.36	1752.84	4.53*
Abduction	53	12	54	29	4320.77	482.23	1.30
Adduction	31	12	55	7	4865.35	204.40	.49
Total	84	14	112	56	6510.63	73.33	.13
PRONE							
Medial rotation	39	10	59	19	3617.82	33.87	.11
Lateral rotation	34	10	54	14	2844.32	659.66	2.71
Total	73	16	105	41	8458.98	929.85	1.28
SITTING							
Medial Rotation	29	9	49	13	2589.08	210.93	.95
Lateral Rotation	30	9	48	12	2037.60	532.26	3.05**
Total	61	14	89	33	5615.63	1225.92	2.55

*Significant difference at 5% level of confidence
**Significant difference at 1% level of confidence

SUMMARY TABLE OF JOINT MOVEMENT RANGES (Cont'd)

Joint and Type of Movement	Mean	S.D.	M+2 S.D.	M-2 S.D.	SS_T	SS_b	F-ratio
KNEE:							
PRONE							
Voluntary Flexion	125	10	145	105	1859.35	1974.69	8.10**
Forced Flexion	144	9	162	126	1709.13	1222.14	8.34**
STANDING							
Voluntary Flexion	113	13	139	87	4979.16	1428.50	3.35*
KNEELING							
Forced Flexion	159	9	177	141	1240.43	1529.92	14.38**
SITTING							
Medial Rotation	35	12	59	11	3858.28	859.37	2.60
Lateral Rotation	43	12	67	19	4404.23	275.02	.72
Total	78	16	110	46	8591.47	733.99	1.06
ANKLE:							
Flexion	35	7	49	21	1245.13	586.37	5.49**
Extension	38	12	62	14	3634.31	1290.03	4.14*
Total	73	14	101	45	4287.02	2571.38	7.00**
FOOT:							
Inversion	24	9	42	6	2548.02	437.44	2.00
Eversion	23	7	37	9	1411.73	144.59	1.19
Total	47	13	73	21	5255.51	990.07	2.20
G P ANGLE:	102	7	116	88	1778.17	102.10	.85

*Significant difference at 5% level of confidence
**Significant difference at 1% level of confidence

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